Effect of Polyvinyl Alcohol (PVA) Film Thickness on Some Optical Parameters

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Abstract

Transparent films of Polyvinyl Alcohol with different thicknesses were made by applying solution casting technique at a temperature of (70°C). The optical absorption and transmission spectra were accomplished for all samples at room temperature over the wavelength region (190-1100) nm. Studying the effect of film thickness, which is measured with micrometer with an error not exceeding (5%), on optical parameters gives an indication that all these parameters are affected with thickness. The experimental results for Polyvinyl Alcohol films show that the optical energy gap decreases by the increasing of film thickness. The absorption coefficient, refractive index, extinction coefficient and real and imaginary parts of dielectric constant are increased by increasing the film thickness.

Keywords: Polyvinyl Alcohol, optical parameters, casting technique, thickness effect.

تأثير سماكة أغشية البولى فينيل الكحول (PVA) على بعض المعلمات البصرية

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الخلاصة

حضرت أغشية البولى فينيل الكحول الشفافة بسماكات مختلفة باستعمال طريقة الصب عند درجة حرارة (70 °C). سجل طيفا النفاذية و الامتصاصية عند درجة الحرارة الغرفة ضمن مدى الطول الموجي nm(190-1100) . دراسة تغير السماكة للاغشية المحضرة اظهرت ان جميع المعلمات البصرية تتأثر بهذا التغير. وقد تم اخذ قياس السماكات للعينات المحضرة بالمايكروميتر وبنسبة خطأ لا تزيد عن (5%). و بينت النتائج العملية ان فجوة الطاقة البصرية تقل مع زيادة سماكة الآغشية المحضرة. ويزداد معامل الامتصاص، ومعامل الانكسار، ومعامل الخمود، ثابت العزل الكهربائي بجزئية الحقيقي والخيالي مع زيادة سماكة الاغشية.

الكلمات المفتاحية: البولى فينيل الكحول، المعلمات البصرية، طريقة الصب، تأثير السماكة.

Introduction

Generally, the use of most polymers was limited to the manufacture of cheap products which were used for simple purposes. However, the rapid technical development has required the replacement of some materials being used in industry with others having better specifications. Consequently, polymers have replaced Aluminum and Iron for some purposes that require stress and high temperature [1,2]. Later, the development of polymer science has started to increase by leaps and bounds. Nowadays, scientists seek to produce, cheap, flexible and multi-purpose polymers. They are used in housing, automobiles and they can be used for different industrial applications. Plastics are the most useful materials used in different industries such as aircraft, packaging, electrical equipment and as electrical insulators. They have increasingly an important role in the production of satellites, space researches and thermal barriers [1,2]. Plastics have supplanted metals in numerous applications. They have superseded steel and numerous different metals in being disintegration safe and synthetically inactive. Having higher temperature extension and specific heat than metals, plastics have been used for fabricating and lining of reactors, absorption towers and the construction of pipes and valves. Most of plastics are currently manufactured as light, rigid and foamy materials and used as insulators due to their low thermal and electrical conductivity. Plastics have almost no free electrons but recent scientific and technical breakthrough have succeeded in making some modifications on regular plastics and brought in to existence of a new generation of plastics that combine the electrical features of the conductive and semi- conductive materials and the mechanical and chemical features of plastics [2,3]. (PVA) is one of the most essential polymeric materials as it has many applications in industry and is of reasonably low cost everybody knows about polymers [4]. Because of the presence of long covalently bonded chains of atoms, PVA is widely used in plastics, pitches, glues, and glue tapes. They are a helpful class of materials, with properties of a given type often having enormously different values for different polymers and even sometimes for the similar polymer in different physical conditions [5]. (PVA) is the largest synthetic water-soluble polymer produced in the world [6]. (PVA) has excellent film forming, emulsifying, and adhesive properties. It is likewise resistant to oil, grease and solvent. PVA is neutral and nontoxic, as well as has high oxygen and aroma barrier properties [7].

Optical properties

The absorption coefficient is connected to the valuable data that can be obtained such as the electronic band structure and the optical energy band gap. From the optical absorption spectrum, the absorption coefficient α (ν) can be estimated from the following equation [8]:

$$\alpha(\nu) = 2.303\frac{A}{d} \qquad (1)$$

Where d is the thickness of the film in cm and is defined by $\log\left(\frac{I_0}{I}\right)$ where I_0 and I are the intensities of the incident and transmitted beams respectively. From the optical data optical absorption can be investigated according to the following relationship [9]:

$$\alpha(\nu)h\nu = B\left(h\nu - E_g^{opt}\right)^r \qquad (2)$$

where α is the absorption coefficient, ν is the frequency, h is Planck’s constant, B is constant, E_g^{opt} *is the* optical energy gap and r is the power that describes the transition process. Specifically, r can take the values $\frac{1}{2}, \frac{3}{2}, 2\ and\ 3$ for transitions titled as direct allowed, direct forbidden, indirect allowed and indirect forbidden respectively [10]. The value of optical energy gap E_g^{opt} was investigated by plotting of $(\alpha h\nu)^{\frac{1}{r}}$ against $h\nu$. The optical transitions caused by photons of energy $h\nu < E_g^{opt}$, the absorption of photons is related to the existence of localized tail states in the forbidden gap. The width of this tail, called Urbach tail, is an indicator of the imperfections levels in the forbidden band gap. The width of the Urbach tail was calculated by using the following equations [11]:

$$\alpha(\nu) = \alpha_0 exp\left(\frac{h\nu}{\Delta E_t}\right) \quad (3)$$

Where, α_0 *is constant and* ΔE_t, is the Urbach energy tail. [12].

From values of transmission (T), and Absorbance (A), the reflectance (R) has been found using the relationship:

$$R + T + A = 1 \quad (4)$$

The refractive index (n) for normal reflectance, was determined from the equation below:

$$n = \frac{(1+\sqrt{R})}{(1-\sqrt{R})} \quad (5)$$

The extinction coefficient (k) is calculated from the absorption coefficient (α) by the relation:

$$k = \frac{\alpha\lambda}{4\pi} \quad (6)$$

Where λ is the wavelength of the incident photon.

The real (ε_1) and imaginary (ε_2) parts of dielectric constant can be found by the relations [8]:

$$\varepsilon_1 = n^2 - k^2 \quad (7)$$

$$\varepsilon_2 = 2n\,k \quad (8)$$

Materials and method

Polyvinyl alcohol (PVA) with molecular weight (10000g/mole), provided by (BDH chemicals, England) with high purity (99.999%) was used as polymeric materials in this research. (PVA) films were prepared by casting technique, (1g.) of pure (PVA) has been dissolved in (15ml) of distilled water to prepare a pure PVA film, the dissolution was stirred for (1hr) using a magnetic stirrer at temperature (70 °C), the solutions were poured on a glass plate with various diameters to obtain films with various thickness. All the prepared films were left to dry at room temperature for (48hr). The thickness of the films was (0.05-0.13) mm, it was determined using micrometer with an error not exceeding (5%), the measurement took out at different places in each film and an average was taken. These films were clear and transparent. The absorbance and transmittance spectra were recorded at room temperature using double beam Shimadzu UV/VIS- 160A in the wavelength range (190-1100) nm.

Result and Discussion

The most creative methods in developing and understanding optical energy gap and the structure of polymers is the investigation of the optical absorption spectrum. At room temperature (UV/VIS) absorption spectra of the PVA films in the wavelength range (190-1100) nm were carried out. For all the prepared films the change of the optical absorption with wavelength is shown in Figure (1). The absorbance increases as the thickness of the film increases, the absorption edge shifts toward higher wavelengths (red-shift). This may be attributed to the creation of levels at the energy band by increasing thickness and this leads to the shift of peak to smaller energies (lower frequencies).

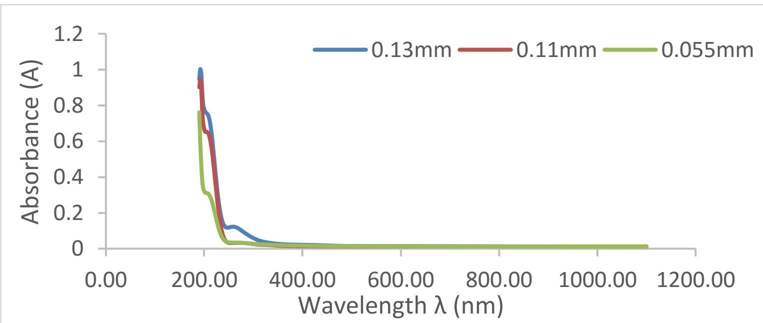

Figure 1: Absorbance versus wavelength for the films

Figure (2) shows the optical transmittance in the UV-NIR regions of PVA films with different thicknesses. The average value of the transmittance in the visible range (over (500 nm) to (800 nm)) range is above (78%) for the PVA films whereas by increasing the thickness, the optical transmittance decreased. This is in agreement with the same trend reported by earlier workers for different solid polymer electrolytes [10-12].

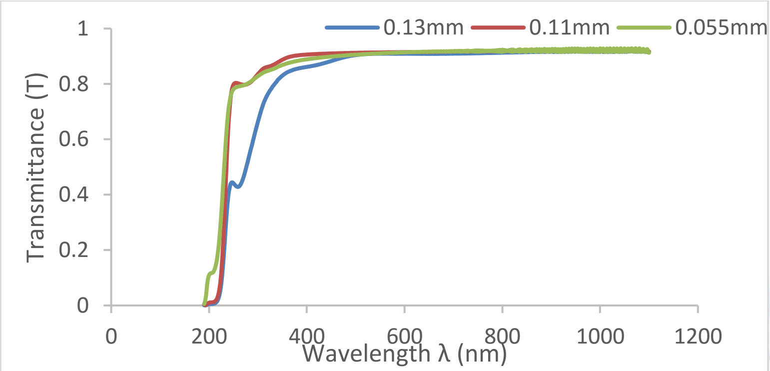

Figure 2: Transmittance versus wavelength for the films.

Figure (3) shows that for all films, the refractive index values (n) are affected by the film thickness. Increasing the film thickness causes the refractive index to increase which may be related to an increase of the density of the film. For all films, refractive index (n) decreases as the photon energy increases until (500 nm) and then becomes nearly constant even with increasing photon energy.

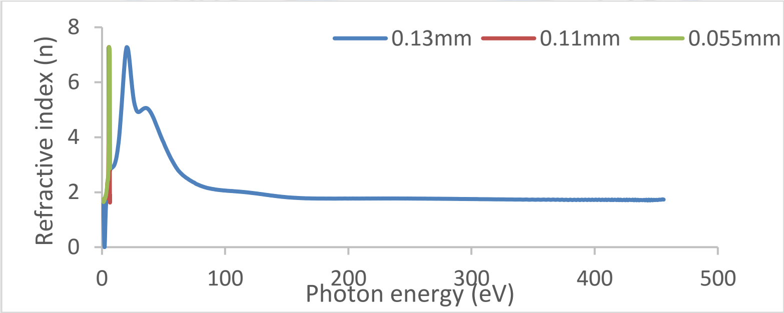

Figure 3: Refractive indices (n) versus photon energy for the films.

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The extinction coefficient (k) increases with increasing film thickness, as in Figure (4) which shows the change in extinction coefficient (k) as a function of the photon energy.

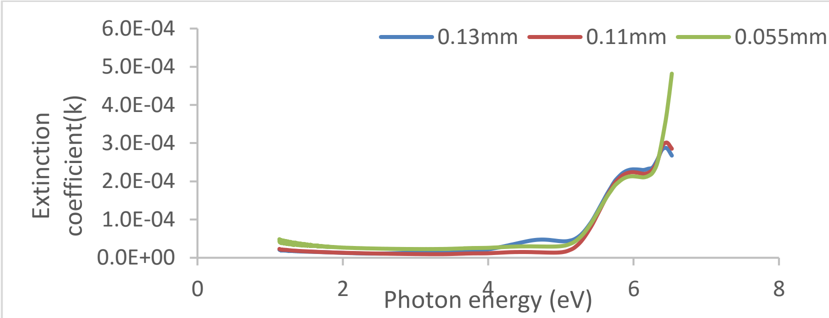


Figure 4: Extinction coefficient (k) versus photon energy for the films.

Figure (5) and Figure (6) display real (ε_1) and imaginary (ε_2) parts of dielectric constant values dependence of photon energy. (ε_1) and (ε_2) values of the films increase as the film thickness increases. The real and imaginary parts of the dielectric constant indicate the same pattern and the values of real part are higher than imaginary part.

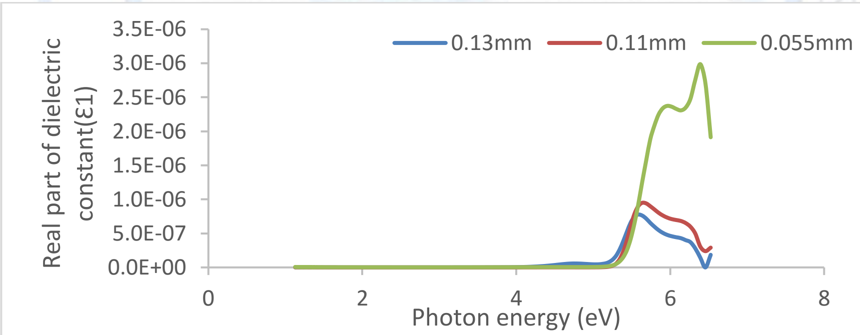


Figure 5: Real part of dielectric constant $Ɛ_1$ versus photon energy for the films.

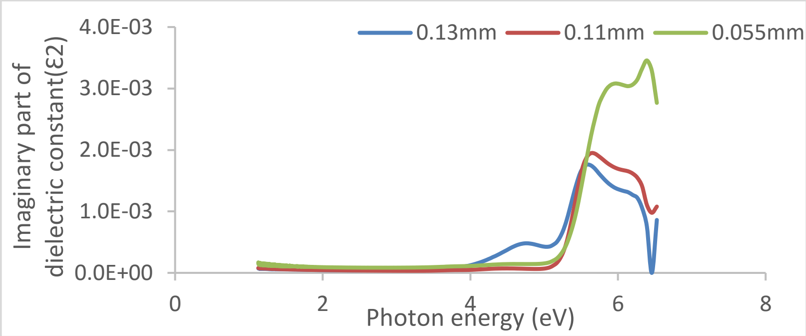
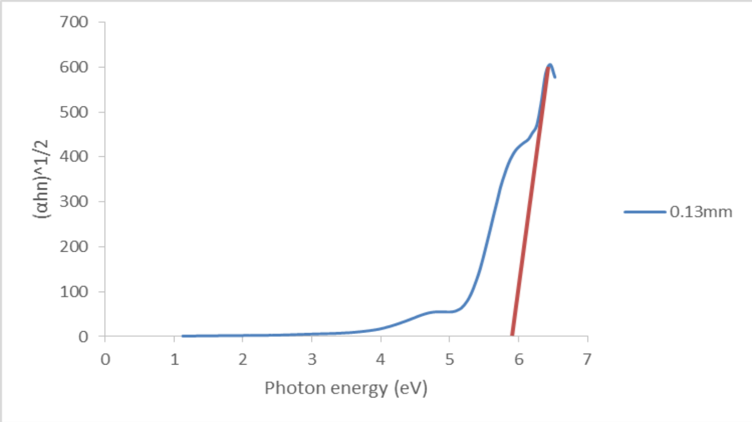


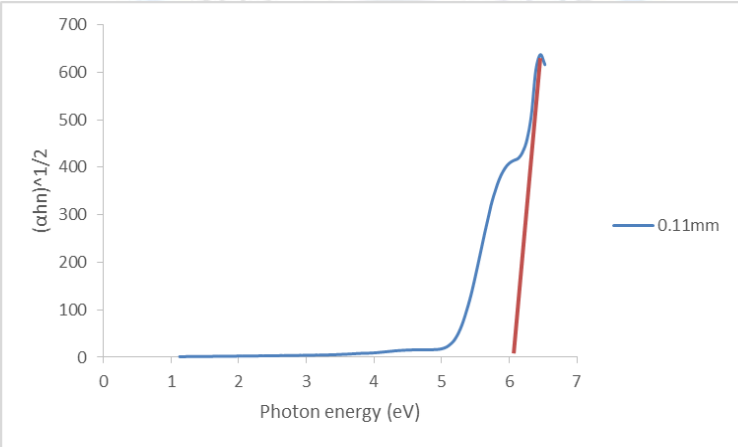
Figure 6: Imaginary part of dielectric constant ε_2 versus photon energy for the films.

Figure (8) shows the relation between $(\alpha h\nu)^{\frac{1}{2}}$ for PVA films with different thicknesses and the photon energy. The energy gap (Eg) for allowed indirect transition has been calculated by using the following equation [13]:

$$\alpha h\nu = B\left(h\nu - E_g\right)^2$$

By drawing a straight line from the upper part of the curve toward the (x-axis), we obtained the energy gap (E_g) for the allowed indirect transition at the value $(\alpha h\nu)^{1/2}=0$. Values for all films are shown in Table (1).





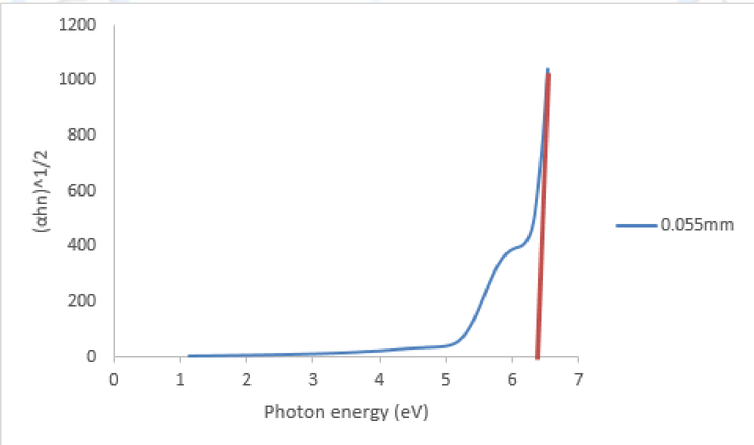


Figure 8: The energy gap values for (PVA) films

Table 1: Energy gap (E_g) values for all (PVA) films with different values of thickness.

PVA thickness (mm)	Allowed indirect E_g (eV)
0.13	5.92
0.11	6.10
0.055	6.4

The values of energy gap (E_g) decrease by the increase of the thickness of the films.

Conclusion

The PVA films have been prepared successfully by casting method. The study of the effect of thickness on optical properties has shown that all the optical properties such as absorbance, transmittance, absorption coefficient, refractive index, extinction coefficient, and the real and imaginary parts of dielectric constant have been affected by increasing the thickness. The optical energy gap increased when the thickness of films was increased.

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